Pedestrian Access to Roundabouts: Closed Course Test of Yielding Vehicle Detection System

Gregory Davis and Vaughan Inman

Abstract. Numerous issues have been raised concerning the accessibility of roundabouts to visually impaired pedestrians. Among these issues are: (1) that motorists do not yield to visually impaired pedestrians if the crossing is not signal controlled; (2) at uncontrolled crossings, visually impaired pedestrians must wait and listen for safe gaps in traffic before crossing, however, at roundabouts, noise from traffic may be continuous, because there are no signals to stop traffic and create gaps; and (3) during peak traffic periods, gaps large enough to be detected by visually impaired pedestrians are infrequent. The study reported here is evaluating a method for assisting the visually impaired to detect the presence of yielding vehicles. In this study, conducted on a mock double-lane roundabout, yield detection performance is assessed with and without a pavement treatment that is intended to provide enhanced sound queues.

INTRODUCTION

The concern has been raised that roundabouts are not accessible to visually impaired pedestrians (US Access Board, 2002; Pietrolungo, 2000). Some recent research has supported this concern, at least for the case where traffic volumes are high (Guth, et al, 2002). The problem, as summarized by the United States Access Board (2002), consists of three parts:

1. Motorists do not yield to visually impaired pedestrians where the crossing is not signal controlled, regardless or whether the crossing is at a roundabout or some other location.
2. Before crossing at uncontrolled crossings, blind pedestrians must wait and listen for safe gaps in traffic. However, at roundabouts, circulating traffic noise may be nearly continuous, and visually impaired pedestrians have difficulty hearing gaps that may occur.
3. At high traffic volume roundabouts, or during peak traffic periods at lower volume roundabouts, gaps large enough to be detected and used by visually impaired pedestrians are infrequent.

The Americans with Disabilities Act (ADA) requires equal access to transportation facilities. The United States Access Board (2002b), which is responsible for developing guidelines for the implementation of the ADA, is currently considering guidelines for providing pedestrian access at roundabouts. The current research is intended to contribute to an empirical basis for those guidelines.

Research Goal

The goal of this research is to evaluate a method for alerting visually impaired pedestrians that motorists have yielded to them.

Roundabouts

Modern roundabouts are circular intersections with specific traffic control and design features that distinguish them from traffic circles and older roundabouts. These features include: yield control at entry, channelized approaches, and geometric approach curvature (deflection) to induce entering traffic to slow to the design speed of the circular pathway. The typical locations for crosswalks at roundabouts are illustrated in Figure 1. Note that one end of each crosswalk terminates on a splitter island. With splitter islands, pedestrians cross only one direction of traffic at a time. Because roundabout crosswalks are set back from the intersection, conflicts with turning vehicles are minimized. Because all traffic is forced to travel on a curved path, vehicle speed is minimized, typically to around 20 mi/h. Additional information on the design of roundabouts may be found in the FHWA publication *Roundabouts: an Informational Guide* (Robinson et al., 2000).

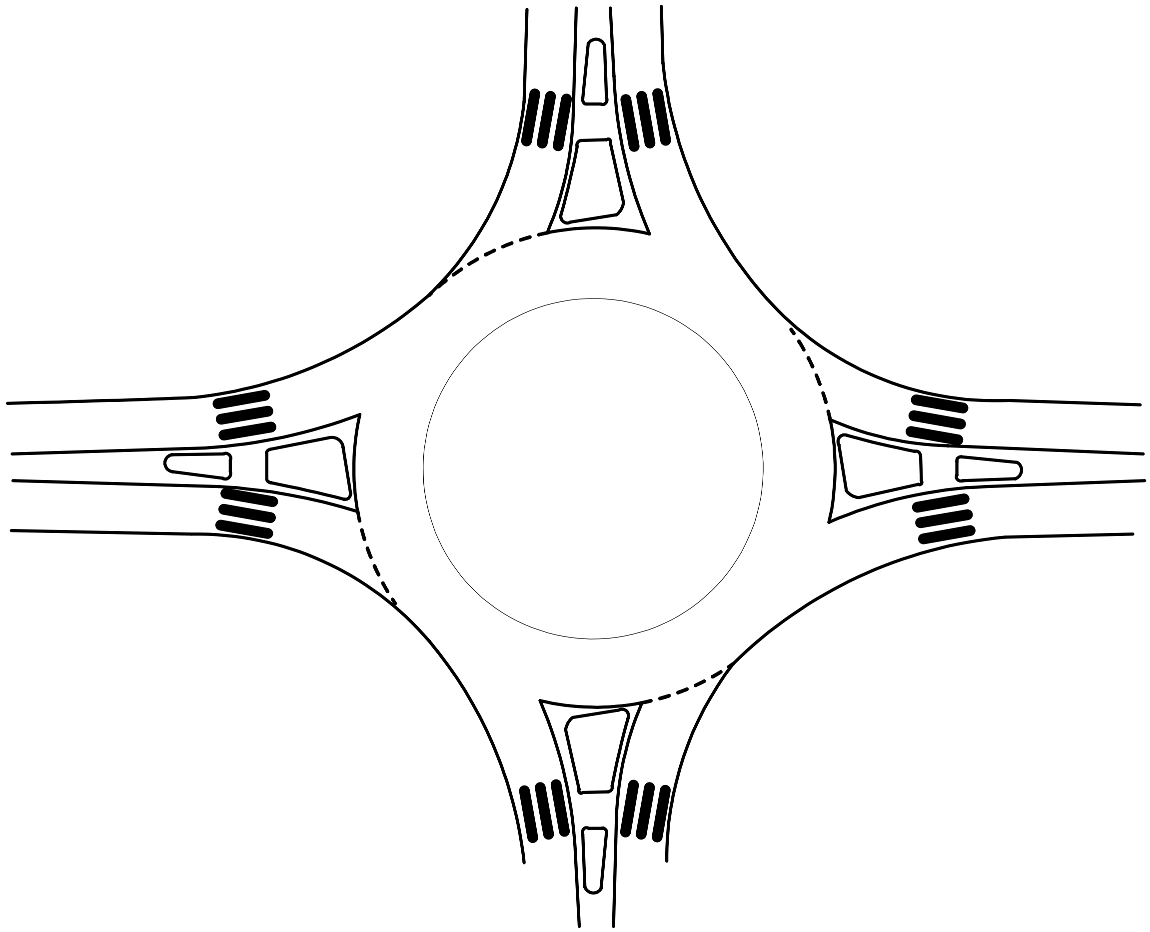

Figure 1. Illustration of single-lane roundabout with crosswalks.

Roundabouts are appearing with increasing frequency in the US, primarily because of their traffic operations and safety benefits. Operationally, they usually result in less delay than signalized intersections, and can also produce less delay than stop controlled intersections (Robinson et al., 2000). Numerous studies have shown that roundabouts have fewer injury related crashes compared to conventional signalized intersections, and most studies also show that the overall crash rate is reduced when conventional intersections are replaced with roundabouts (Robinson et al., 2000; Persaud et al., 2001). In addition, because roundabouts reduce speed, pedestrian death and serious injury rates are lower at roundabouts than at conventional signalized and unsignalized intersections (Robinson, et al., 2000).

The Study

The primary hypothesis evaluated in this experiment is that the presence of infrastructure generated sound cues will increase the proportion of yielding vehicles that visually impaired pedestrians can detect. An important corollary of this hypothesis is that visually impaired pedestrians will be able to detect when vehicles have yielded in both the right and left lane of a double-lane roundabout. Without a supplementary sound cue, the noise generated by a vehicle yielding in the near lane frequently masks the sound of a second vehicle yielding in the far lane. Thus, even when blind pedestrians detect that one vehicle has yielded, which itself can be difficult, they may not cross because they cannot detect whether the remaining lane is open, or blocked by another yielding vehicle.

Traffic approaching, circulating, and exiting at roundabouts generates noise that may make it difficult for the visually impaired pedestrian to detect crossable gaps in traffic. Crossable is usually defined by the orientation and mobility community as a gap in traffic large enough to be detected and allow the pedestrian to reach the far side of the street or splitter island before a vehicle arrives. Guth et al, observed that after a vehicle has passed a crossing location, the noise from the departing vehicle may continue to mask approaching vehicles for the next 3 s. Thus, at the exit of a double-lane roundabout that has 12 ft lanes, a blind pedestrian might require a gap of 9 s between vehicles: 3 s for the first vehicle's sound to diminish, and 6 s to cross two lanes at a speed of 4 ft/s. At busy roundabout exits, 9-second gaps may be rare. Gaps that the visually impaired pedestrian can recognize or detect may be rarer still, because vehicles not using the exit may either (a) mask the sound of a 9-second gap, or (b) be driving where they could reach the exit crosswalk in less than 9 s, even though they are not intending to use that exit. The lack of detectable 9-second gaps need not have a detrimental effect on mobility if (a) drivers would yield when they see blind pedestrians waiting to cross, and (b) the blind pedestrian could detect that motorists have yielded. This study addresses the latter of these requirements. We are currently conducting a separate study to address the former requirement.

At double-lane roundabouts, the pedestrian needs to decide when it is safe to cross two lanes. Note that *safe* is a relative terms, and depends on the perceptions and biases of individuals. Each pedestrian must decide for them self when the benefits of crossing outweigh the potential risks, and this decision is idiosyncratic, and potentially complex decision. Thus, the decision to cross is never a black and white decision.

At a double-lane roundabout crosswalk, when one vehicle yields, the visually impaired pedestrian may prefer that vehicle to proceed so that its idling does not mask the sound of other approaching vehicles. In this case, drivers that yield may simply add to the delay for both the blind pedestrian who cannot tell whether it is safe to cross, and for the drivers. Motorist frustration at such delays could subsequently result in increased reluctance to yield. Ideally, to minimize delay and frustration for both pedestrians and motorists, pedestrians would leave the curb and cross as soon as motorists have yielded. This study is intended to develop an auditory cue that blind pedestrians could use to promptly detect when vehicles have yielded.

Several cuing methods have been conceptualized. Current ideas range from ridges or grooves in the pavement that generate distinctive sounds, to detectors that trigger electronic auditory or tactile messages. The ideal solution would be easily and intuitively understood by visually impaired pedestrians and would be simple and inexpensive to deploy.

Method

Independent Variables

Currently, we have fabricated a system made from longitudinally cut sections of PVC pipe that generate clacking sounds when a vehicle passes over them. This system may be sufficient for concept testing, but would need further refinement and testing before it could be considered as an engineering solution.

One strip is placed across both lanes about one foot upstream of the upstream edge of the crosswalk, and two additional strips are placed across both lanes 20 and 24 ft upstream of the first strip. A two-axel passenger car that passes over the strips generates a rapid “clack, clack, clack, clack” sound as the two axels pass over the first two strips, and then, after a brief delay, another “clack, clack” as the vehicle enters the crosswalk and departs. If the pedestrian hears the first four clacks, but not the second two, then a vehicle has yielded. Figure 2 shows the test implementation at the exits of a double-lane roundabout.

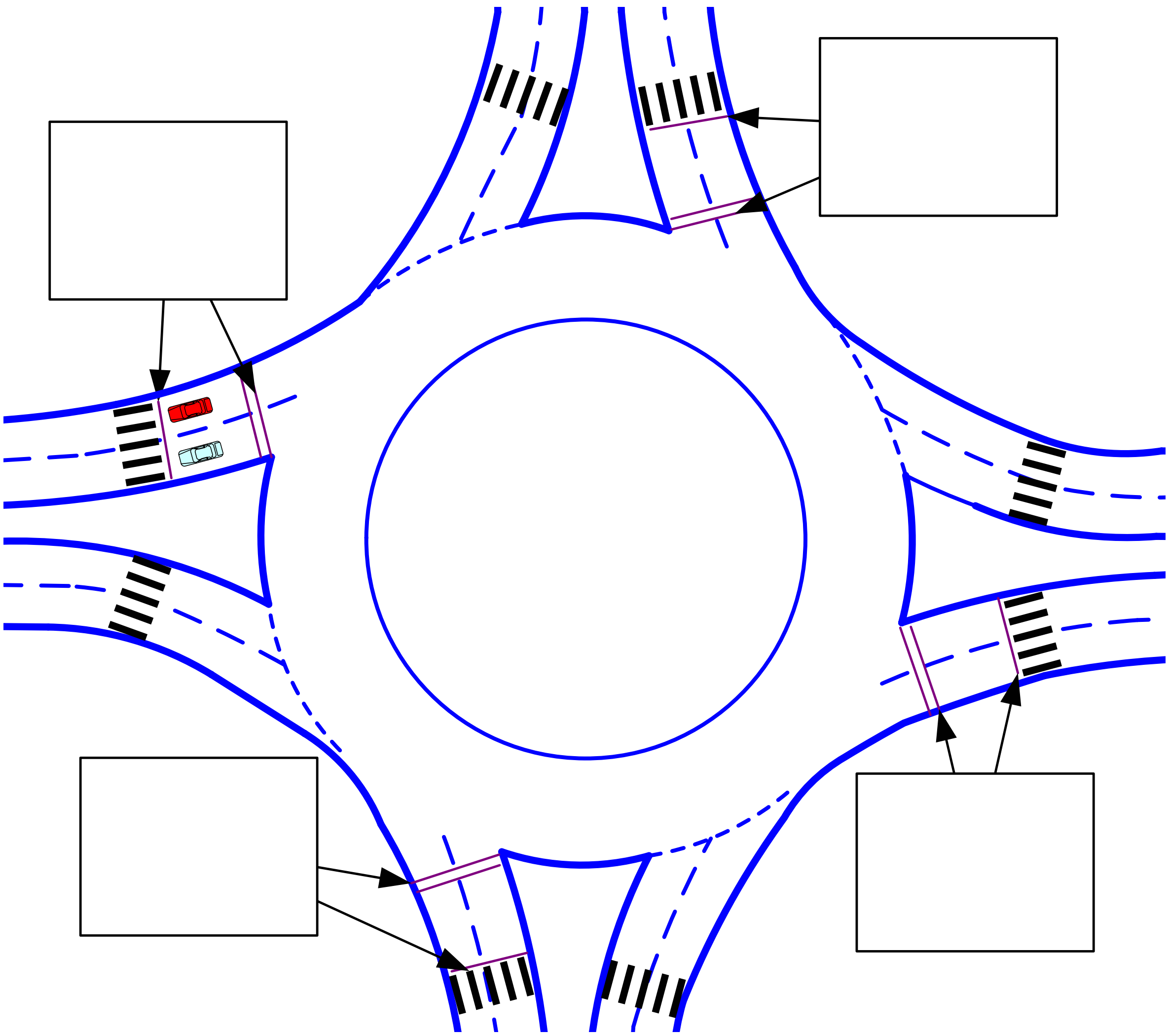

Figure 2. Drawing of double-lane roundabout with noise generating strips placed at the exits.

The test is being conducted on a closed road at the Federal Highway Administration’s Turner-Fairbank Highway Research Center (TFHRC). The layout of the test course is shown in Figure 3. In the absence of a roundabout at the TFHRC, this newly paved test course creates a sound environment similar to that of a double-lane roundabout. The participant and certified Orientation and Mobility Specialist stand 4 ft from the edge of the roadway near the crosswalk, as indicated in the lower left portion of Figure 3. The experimenter is stationed opposite the participant and communicates by a walkie-talkie and a system of flags to research assistants who drive four vehicles around the test course. In addition to placing noise-generating strips upstream of the crosswalk, strips are placed at three additional locations. The additional locations serve as a check to verify that participants are not confused by noise from strips at crosswalks that might be nearby. The control condition for the double-lane crossing is not at the same location as the crossing that has the strips. Although testing at separate locations is not desirable from an experimental control perspective, it was necessary because the strips are secured to the roadway in a way that is not amenable to rapid removal and reapplication.

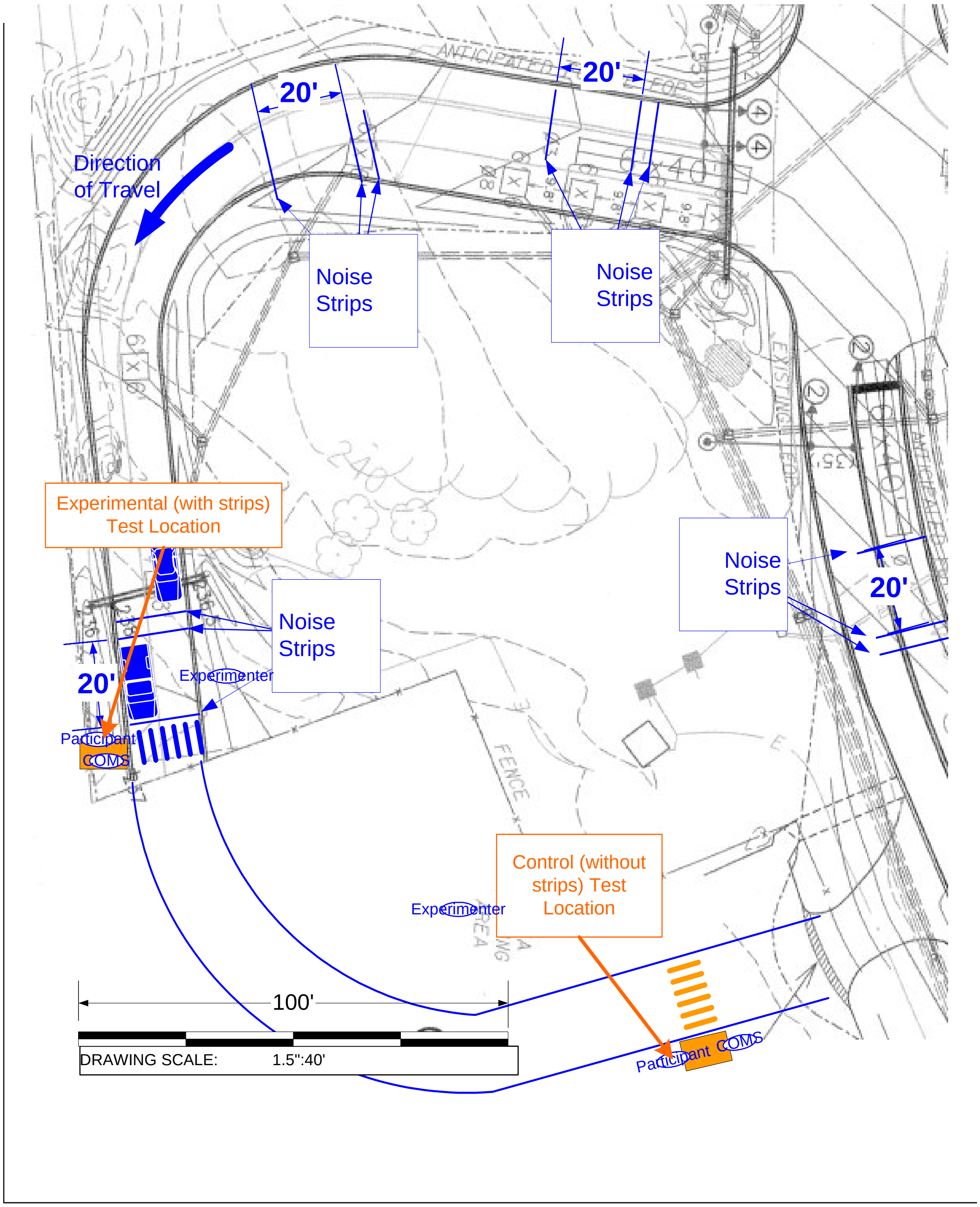

Figure 3. Scale drawing of closed course test layout with test specific information in blue.

Two independent variables are being assessed: (1) *Noise Strips* presence or absence and (2) *Yielding Trial Type*. Yielding has four levels: (1) a vehicle yields in far lane first, followed after a variable delay by another vehicle yielding in the near lane; (2) a vehicle yields in near lane first, followed after a variable delay by another vehicle yielding in the far lane; (3) two vehicles yield at the same time, on in each lane, and (4) a vehicle yields in one lane, but departs after 10 s, before a different vehicle yields in the other lane. If only one vehicle arrives, then the pedestrian needs to detect whether it has yielded regardless of its lane. The lane furthest from the pedestrian may be harder for listeners to distinguish because sound attenuates rapidly with distance. If two cars yield, one in each lane, the pedestrian must be able to detect this, because this would mean that the sound of other approaching vehicles may be ignored — two yielding vehicles provide a protective barrier for a double-lane crossing.

Dependent Variables

The dependent measures in this study are:

1. Accuracy in identifying when lanes are blocked.
2. Latency to identify stopped vehicles.
3. Responses to debrief questions.

Accuracy. Accuracy may be defined as a proportion of correct identifications of yielding vehicles, and this may be reported as a simple proportion. However, there is more than one type of error, and more than one correct response. For development of new technologies it may be important to distinguish between these types. One type of error is *failing to detect* a yielding vehicle. Another type of error is a *false alarm*, in this case, reporting that a vehicle has yielded when one has not. Participants may be correct by detecting stopped vehicles that block lanes, or detecting that the lanes are not blocked. For each trial, a mark can be placed in one of the boxes shown in Table 1. False alarms are of particular concern, because if the visually impaired pedestrian incorrectly believes that a vehicle has yielded, he or she may ignore other vehicles that are approaching and step in front of a moving vehicle. A failure to detect would be inconvenient to the pedestrian, representing delay and a missed opportunity to cross. They may also be inconvenient to motorists who wait while not being recognized. However, failures to detect a car are not a direct safety concern. Therefore, our target is no false alarms, less than 20 percent of failures to detect, and an overall correct detection of a yielded vehicle at least 80 percent of the time.

Table 1. Possible outcomes of detection responses to vehicle yielding.

		Truth					
	Lane Presence	***Left Lane***		***Right Lane***		***Both Lanes***	
		Stopped (yielding)	***Not Stopped***	***Stopped (yielding)***	***Not Stopped***	***Stopped (yielding)***	***Not Stopped***
Response	***Stopped (yielding)***	Correct Detection	False Alarm	Correct Detection	False Alarm	Correct Detection	False Alarm
	No Vehicle Present	Failure to detect	Correct Rejection	Failure to detect	Correct Rejection	Failure to detect	Correct Rejection

Latency. Four latency measures are recorded:

1. latency to recognize that the near lane is blocked;
2. latency to recognize that the left lane is blocked;

3. latency to recognized that both lanes are blocked; and
4. latency to recognize that a previously stopped vehicle has moved on.

Of these, the 3rd is most important, because if correct, it indicates that it might be reasonable to begin crossing.

Debrief responses. A semi-structured interview is used to debrief participants. That is, we ask all the participants the same core questions, but answers are open-ended and unplanned follow-up questions may be asked to obtain clarification and expansion on open-ended responses.

The semi-structured interview has to following format:

1. Do you have any comments on the tasks you just completed?
2. Did you notice any differences between the two locations used in the test?
3. When using a crossing of two or more lanes and no traffic signal, what do you normally do if a driver yields for you?
4. What cues did you use to detect:
   - That vehicles have yielded?
   - Not yielded?
   - Yielded, but then gone on?
5. Would the “clackers” that you heard today provide you with a better, or more reliable, indication that cars have yielded than you would have otherwise? Note that different terms were used for the plastic strips with different participants. “Clackers” was one term. Another participant called them “seams in the road”, and yet another called them “bumps”. The participant’s term was used in the interview.
6. Have you had any experience crossing roundabouts? If no, or if the response indicates that the participant does not understand modern roundabouts, a description of roundabouts is provided. The description is followed by a discussion of questions or concerns. The description includes use of a felt board with raised markings, attached with Velcro, to delineate roundabout features.

The 2nd question is important, because participants are not told about the noise generating strips until after data collection is completed. At both test crosswalks, participants first listen to passing traffic, then to passing and yielding traffic. They also practice the hand signals that are used to indicate their responses. We use hand signals so that participants can listen to the traffic without interference from voice communications, and so that we can record their responses on video along with the behavior of the vehicles to which they are responding.

For future deployment of yield cueing devices, the amount of training that is required may be crucial to success. There is currently no reliable means of disseminating training to pedestrians, particularly to blind pedestrians, who are already traveling independently and may have been doing so for years.

Prior to data collection in the mock roundabout, a background interview is conducted to determine:

- Participant's current age.
- Participant's current pedestrian travel behavior.
  - Frequency of pedestrian trips outside of the home or office.
    - Alone.
    - With companion.
  - Frequency of pedestrian trips to unfamiliar locations.
    - Alone
    - With companion.
- Whether the participant uses visual cues when traveling.
- Whether wearing a blindfold would interfere with the participant's ability to travel independently.

The last two questions are important, because many individuals who are legally blind, i.e., have less that 20/200 corrected vision, are completely without visual ability. To control for variability in visual ability, we required participants to wear a blindfold if they had any residual vision. Individuals who indicated that a blindfold would degrade their ability to travel independently, or were uncomfortable with a blindfold for any reason, were asked not to participate.

Participants

At this writing, 5 visually impaired pedestrians have been tested. All reported that they travel independently and take pedestrian trips to unfamiliar locations. Their ages range from 23 to 72 years. Three were male and two were female. Two reported complete vision loss. The others had very limited visual ability, but wore a blindfold during the test, and reported that the blindfold would not adversely affect their ability to travel independently.

Procedures

Testing was done at the Intelligent Intersection Test Facility at the TFHRC in McLean. The layout of this facility is indicated in Figure 3. Participants were tested individually.

Before data collection began, the participants were given instructions, and were provided an opportunity to explore the mock intersection. At that point, 4 of the 5 requested that they be allowed to cross the streets so that they could determine the length of the crosswalk (which was 5.8 m). An orientation and mobility specialist was always present during the pre-test, test and debriefing sessions.

The noise generating strips were not explained or mention to the participants until after data collection, and no participant asked about them.

During each trial, up to four vehicles looped continuously through the course. Top speed was 15 mi/h, and speed on turns was lower. The participant and orientation and mobility specialist stood 1.3 m from the edge of the roadway. To increase the ambient noise level, loud speakers on both sides of the participant played recorded traffic noise. The sound level was set to 68 dB C, measured at the position of the participant's head. This sound level was selected because it is the ambient traffic sound level at the crosswalk threshold of the roundabout that will be used in a later field test phase of this research.

During the test, up to four vehicles circulate around the mock roundabout. The drivers are FHWA or contract employees who follow scripted instructions for yielding or not yielding on a particular lap. The scripts comprise 18 trials that are repeated at each of the two crosswalks. The scripts are designed such that there are 7 trials in which the near (right) lane yields first, 7 trials in which the far (left) lane yields first and four trials in which both lanes yield at the same time. The scripts roughly balance the lanes that each of the four vehicles use, and the order in which each vehicle passes the crosswalk. On any particular trial each vehicle makes between 0 and 4 complete laps. On some trials one or two of the vehicles do not move. The scripts are designed to obscure the number of vehicles and the amount of time between the start of a trial and its completion, and the time between the first vehicle yield and the second. On two trials, the first vehicle to yield pulls away after 10 s, so that on those two trials, both lanes are never blocked at the same time. The scripts also call for drivers to vary their speed as they pass the crosswalk. Although the same 18 scripted trials are used at both crosswalks and for all participants, a different randomized order of trials is used each time. Table 2 shows instructions to the drivers for a single trial. In this trial vehicle 2 yields on its second lap and vehicle 3 yields on its third lap. Although not indicated in the example, vehicles 1 and 3 used the far (left) lane and vehicles 2 and 4 used the near (right) lane.

Table 2. Example script for drivers.

Driver	**Instruction**
1	Go past the crosswalk 3 times, and then return to Station A.
2	Go past the crosswalk 1 time (slow), and then yield.
3	Go past the crosswalk 2 times (2nd lap slow), and then yield.
4	Go past the crosswalk 1 time, and then return to Station D.

Participants use hand gestures to indicate that:

- a vehicle is stopped in the near lane,
- a vehicle is stopped in the far lane,
- vehicles are stopped in both lanes,
- a previously stopped vehicle has departed, and
- the immediately preceding gesture was in error.

The actions of the participant and the vehicles were digitally video-recorded for later laboratory analysis.

RESULTS

At the time this report was prepared, we had completed testing of four participants and a fifth had completed the testing with the sound strips only. The following paragraphs summarize the results for individual participants.

Participant 1:

Participant 1 is a middle-aged male. He takes walking trips outside home or office everyday. Most of these trips he travels alone. Many of these trips, almost every day, are to places he has not previously visited. He has some residual peripheral vision, but relies primarily on hearing for street crossings. He wore a blindfold during the test and completed 15 trials with the strips before testing was halted because of rain.

Table 3 summarizes the findings for Participant 1. The first three columns of the table show performance in detecting when vehicles had yielded, or were thought to have yielded, in both lanes. That is, the table does not show detection of yields in the individual lanes, but only potential crossing opportunities when yielding vehicles occupy both lanes. The “n/a” entries are the result of the rain, which prevented completion of all trials.

With the strips in place, he correctly detected when vehicles had yielded in both lanes on 13 of the 15 trials. He had one false alarm. In that case, he thought both lanes were blocked when only the far lane was blocked. Interestingly, another vehicle stopped behind the vehicle in the far lane, and its front wheels could be heard going over one of the noise generating strips. He indicated both lanes were blocked immediately after that vehicle passed over the strip. On the first of four trials when both lanes yielded at the same time, he did not detect the car in the near lane. However, he immediately detected both yielding vehicles on the latter three simultaneous yields.

The longest amount of time this participant needed to correctly detect a yield was 4 s. This was a yield in the far lane while a car was already stopped in the near lane.

He reported that the “seams in the pavement” made it more difficult to hear the car engines, which he has been trained to listen for. He said that he consciously tried to ignore the noise from the seams. When he was told that his only false alarm occurred when a second vehicle drove over a strip when pulling behind a vehicle that had already yielded, he appeared surprised. He said that he thought he had entirely ignored the “seams”, but that maybe he had not. We are trying to schedule him to come back and complete the control (without strips) condition.

He estimates that at signalized intersection he is delayed by at least 4 minutes because he always waits through at least one cycle to be sure he knows what is going on. At some intersections where pedestrian call buttons are installed, he doesn’t use them, because by the time he travels from the button to the crosswalk threshold and gets himself aligned with the crosswalk, the pedestrian phase has expired. At other crossings, he is unable to tell which direction the “accessible” signal is indicating.

Table 3. Participant 1 summary data.

Sound Strips	Correct detection	False alarm	Failure to detect	Departure Detected
Without	n/a	n/a	n/a	n/a
With	86.7%	6.7%	6.7%	n/a

Participant 2:

Participant 2 is an older (over 65 years of age) male. He travels alone outside of home or office everyday. He estimates that about once a month he takes a pedestrian trip to a location he has not been to before. He has no residual vision and therefore did not need to wear a blindfold.

Table 4 summarizes the results for Participant 2. The right most column of the table refers to the two trials with strips and two trials without strips in which vehicles yielded for 10 s, but then departed before a second vehicle yielded in the other lane.

He correctly identified when both lanes were blocked 11 times with the strips and only three times without the strips. With the strips, he had two false alarms (indicating both lanes were blocked when at least one was not). He also had two false alarms without the strips. When both vehicles approached the crosswalk and yielded at the same time, his performance was markedly better with the strips: With the strips, he correctly detected 3 simultaneous yields and had 1 failure to detect. Without the strips, he had 4 failures to detect and detected yields in the far lane only 6 out of 18 occasions. With the strips, he failed to detect only one of the 18 yields in the far lane. Clearly, the strips greatly increased his ability to detect that vehicles had yielded. However, the strips did not seem effective in reducing false alarms.

This participant said he sometimes crosses at uncontrolled crosswalks that have more than 2 lanes, even when only one lane is blocked. For instance, if it is otherwise quiet, he will walk in front of a vehicle that has yielded in the near lane so that he can better hear traffic the far lane. This strategy is worrisome in light of the fact that both his false alarms were false detections of vehicles in the near lane, that is, on two occasions when vehicles had yielded in the far lane, he thought they had yielded in the near lane. In these cases his strategy of walking in front of a vehicle he thinks has yielded in the near lane would have left him exposed to vehicles approaching in that lane.

He indicated that he noticed the noise strips but did not realize that they were intended to help detect yielding vehicles. He said he tried to use the information they provided. He indicated that he did not know the number or location of the strips, but that such knowledge would have helped.

Table 4. Participant 2 summary data.

Sound Strips	Correct detection	False alarm	Failure to detect	Departure Detected
Without	18.8%	12.5%	68.8%	2 of 2
With	68.8%	12.5%	25.0%	1of 2

Participant 3:

Participant 3 is a young adult female. She takes 6 to 12 pedestrian trips outside the home or office every week. About half of these are with a sighted companion. She estimated that about once a month she takes a pedestrian trip to a novel location. She has no residual vision. She did not wear a blindfold during the test.

Table 5 summarizes the findings for Participant 3. Without the strips, she correctly identified when both lanes were blocked on 8 of 16 trials and had 2 false alarms. She did no better with the strips: she correctly identified when both lanes were blocked on only 6 of 16 trials and had 3 false alarms. She detected 1 of 4 simultaneous yields both with and without the strips. Both simultaneous yield detections took between 9 and 10 seconds – she was clearly listening for idling engines, not to pavement sounds. She stated that she was trained to listen to engine noise, not tire noise.

Note: one possible explanation for her poor performance was that the background sound level may have been calibrated incorrectly to 78 dB C instead of the intended 68 db C.

On a positive note, she indicated that she learned a lot during the test. For instance, she says she learned that it is easier to detect vehicles in the near lane. The data support this observation: with the strips she detected 18 of 18 near lane yields. Without the strips, her performance in detecting vehicle near lane yields was comparable: 17 of 18 near lane yields. She volunteered that the “bumps” made it harder to hear the car engines.

She said that at uncontrolled crossings, if a car yields for her, she normally waves it on. At first, she said she would never cross in front of a yielding vehicle if there were more than one lane. Later she amended this by saying that if she could tell that there were no other cars, she would cross in front of a single yielding vehicle, but added that her experience with the test indicates that she could probably never tell if there were no other vehicles.

Table 5. Participant 3 summary data.

Sound Strips	*Correct detection*	*False alarm*	*Failure to detect*	*Departure Detected*
Without	50.0%	12.5%	37.5%	2 of 2
With	37.5%	18.8%	43.8%	2 of 2

Participant 4:

Participant 4 was a middle-aged female who said that she takes about 15 pedestrian trips outside her home or office during an average week. Most of those trips are without a companion. She said that she travels to unfamiliar locations almost every week. She said she does not use visual cues when traveling, but that she has some light perception, which is mainly useful at night. She indicated that wearing a blindfold would not interfere with her travel, and she wore the blindfold during the test.

Table 6 summarizes the findings for Participant 4. Like participant 3, it is possible that the background sound level was calibrated incorrectly to 78 dB C instead of the intended 68 db C. Participant also indicated a right ear hearing loss that we did not verify.

With the strips, she correctly identified when both lanes were blocked on 6 of 16 trials and had 3 false alarms. Without the strips, she correctly identified when both lanes were blocked on 3 of 16 trials with 2 false alarms. With the strips, she detected 2 of 4 occasions when vehicles yielded simultaneously in both lanes. Without the strips, she detected none of the 4 simultaneous yields. The participant had much difficulty detecting vehicles in the far lane, particularly when vehicles were already stopped in the near lane. Most of her false alarms were false reports of yields in the far lane when there was actually a yield in the near lane.

She indicated that the test was difficult because she could not tell from what direction the cars were coming. She noticed the sound of the strips and said they were useful, especially when two vehicles arrived at the same time.

When asked what she does when vehicles yield for her at uncontrolled crossings, she said she just waits until they leave and it becomes quiet. She does not signal drivers to move on, because she is unsure how they will react, and cannot see them to adjust to their reactions. She avoids crossing at intersections without signals. She “hates” stop-controlled intersection because she never knows what cars are going to do. That is, she does not know whether they have stopped for her, or whether they will remain stopped if she decides to cross. She avoids streets with more than 2 lanes if they do not have signals. At signalized intersections, she always waits through at least one cycle so that she is sure what is occurring. She prefers crossing mid-block to crossing at unsignalized intersections. When roundabouts were described to her, she remarked that the crosswalks were too close to the intersection: that the crosswalk would be better if it were mid-block and away from the noise of the intersection.

Table 6. Participant 4 summary data.

Sound Strips	***Correct detection***	***False alarm***	***Failure to detect***	***Departure Detected***
Without	18.8%	6.3%	75.0%	2 of 2
With	37.5%	12.5%	50.0%	2 of 2

Participant 5:

Participant 5 was a middle-aged male. He estimated that he takes about 10 pedestrian trips per week outside of home or office, all without sighted companion. Off these trips, perhaps two per month would be to locations that he had not previously visited. He indicated that he uses his residual vision to locate the white lines that demarcate crosswalks, and also to follow sidewalks. He wore a blindfold during the test, and indicated that it would not interfere with his performance (the crosswalks in this test were not marked, and participants did not cross the road). Although at the time of testing he had never been to a roundabout, he is actively involved in opposing the installation of roundabouts in his community.

Table 7 summarizes the findings for Participant 5. With the strips, he correctly indicated 10 of 16 instances when both lanes were blocked. However, he also had two false alarms. He also correctly detected both instances when stopped vehicles departed. He was about equally proficient in detecting vehicles in the near and far lanes, although he was often uncertain which lane a vehicle was in before both lanes were occupied.

Without the strips, he correctly identified 7 of 16 instances when both lanes were blocked, three fewer than he identified with the strips. However, the slight detection advantage with the strips was offset by the two false alarms with the strips. Without the strips he had no false alarms. As with the strips, he correctly identified both occasions when a previously stopped vehicle departed.

Table 7. Participant 5 summary data.

Sound Strips	*Correct detection*	*False alarm*	*Failure to detect*	*Departure Detected*
Without	43.8%	0.0%	56.3%	2 of 2
With	55.6%	12.5%	25.0%	2 of 2

DISCUSSION AND PRELIMINARY FINDINGS

It had been suggested that it would be inappropriate to train participants to use the strips, because there would be no practical way to train the current generation of visually impaired pedestrians on the use of such a system. Indeed, one of our five participants had received formal orientation on mobility training in 1954.

Therefore, we did not train participants to use the strips, nor did we explain their purpose, or call attention to their to the presence of the strips. Participants were free to ask about the source of the noise from the strips, and any questions they asked about the strips would have been answered. Should anyone have asked, they would be permitted to explore the layout on foot. Thus far, no participant has asked about the strips.

The notion that training is not a feasible for the introduction of new crossing solutions is ironic, in that the majority of participants indicated that they listened for the vehicle engines because of their orientation and mobility training. However, there is currently no research to show that training might improve performance with the cueing system used in this study. We are currently conducting a field test in which some of the participants in this closed-course study are detecting yielding vehicles at an operating double-lane roundabout. Because of their experience and debriefing in the current study, they represent a trained population and may shed light on performance with limited training. In the field study, we are not adding to the existing ambient noise, and this may benefit performance.

All of the participants indicated that orientation and mobility specialists trained them to listen for car engines. Several indicated that they are aware that electric and hybrid engines may be undetectable, and none had a strategy for addressing this issue.

The sound cues provided in this study were helpful to most of the participants. Only one participant did not do better in detecting vehicle yielding with the strips. However, the strips did not prevent false alarms, and they may have resulted in an increase in false alarms. False alarms represent a significant safety risk, as they imply that the participant might have crossed in the belief that both lanes were blocked, when in fact a vehicle could have approached in at least one of the lanes without stopping. Nonetheless, the improvement in detection is encouraging, in that it suggests that a cueing system might work for single lane roundabouts and right turn slip lanes. It also suggests that a similar cueing system might work for double-lane roundabouts if it provided distinct cues for right and left lanes.

Many challenges remain before any new treatment at uncontrolled crossings can be recommended. Even participants who indicated that they might cross in front of a yielding vehicle indicated that they have qualms about doing this, because: (1) they do not know that the driver has stopped for them, and (2) they have no assurance that a stopped driver will remain stopped until they have crossed. Treatments that require training would not provide access to untrained pedestrians, who for many years may represent the majority of visually impaired pedestrians.

The participants we recruit report that they travel independently to places they have not previously visited. This means that they must assess each intersection based on environmental sounds and other context. Currently, there is no way to tell how many lanes need to be crossed at a roundabout, or most other intersections. With accessible pedestrian signals, this is not an issue, because the signals are timed to allow sufficient crossing time. At unsignalized crossings, the blind pedestrian generally has no way of knowing how many lanes need to be crossed, or if there is a pedestrian refuge between opposing traffic flows. Indeed, there is currently no standard way of indicating to blind pedestrians that they are at a roundabout, much less whether the roundabout is single- or multi- lane.

Another complication is the performance of drivers. In the present study, the drivers were instructed to yield between the last strip (near the stop bar) and the two upstream strips. Thus, they usually generated the desired sound cues. In the field, some drivers will "yield" within the crosswalk, and others will yield well before the crosswalk. An informal observation at a double-lane roundabout revealed some drivers yielding to a blind pedestrians from as much as 12 m away. That distance is too great to allow the pedestrian to hear engine noise, and would be too great to trigger sound strips or other detectors if they were installed. In this situation, if other approaching vehicles can be heard, most blind pedestrians would not cross, because they would not know that distant vehicles are blocking traffic. In a short time, the entire intersection might become gridlocked, because the yielding vehicles are stopped in the middle of the circular roadway and the blind pedestrian is waiting for traffic to clear.

A system that indicates in which lanes vehicles are stopped may also be problematic. As suggested in the roundabout informational guide (Robinson, et al., 2000), many drivers prefer the shortest path through a double-lane roundabout. The shortest path frequently straddles the exit lanes. Drivers who yield while straddling two lanes could confuse pedestrians and fail to shield pedestrians from other approaching traffic.

In summary, the FHWA is continuing to test methods for cueing blind pedestrians to opportunities to cross at roundabout crosswalks. The results to date are encouraging, but significant challenges remain to safe, reliable, and efficient access for all users.

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